Monochloramine Disinfection of a Hospital Water System for Preventing Hospital-Acquired Legionnaires' Disease: Lessons Learned from a 1.5 Year Study

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Background & Objectives

Hospital-acquired Legionnaires' disease occurs when patients are exposed to *Legionella*-contaminated water from a hospital water distribution system. Disinfection of hospital water systems has halted outbreaks and prevented future cases. A number of disinfection methods have been used with varying success such that new approaches are needed.

Monochloramine has been used for municipal water treatment for many years and hospitals in these municpalities reported fewer cases of Legionnaires' disease[1, 2, 3]. This made monochloramine an attractive disinfection option for hospitals, however the ability for on-site generation was not available until recently.

Marchesi et al. evaluated monochloramine injection in an Italian hospital and demonstrated a significant reduction in *Legionella* positivity[4]. We report the first U.S. application of monochloramine in a hospital hot water system for *Legionella* disinfection.

The objectives of this study were:

- To evaluate the ability of monochloramine injected into a building hot water system to reduce *Legionella* colonization
- To identify the effects of monochloramine on water chemistry
- To identify key monochloramine system operation and maintenance requirements

Figure 1. The monochloramine generation system

Methods

Location: A 12 story tertiary care hospital in Pittsburgh, PA, USA. *Legionella pneumophila* serogroup 1 was detected in this hospital's hot water system in the early 1990s, which prompted the installation of a copper-silver ionization system. After a building construction/renovation project in 2010, *Legionella* colonization was found to increase dramatically in this building despite disinfection.

The monochloramine injection system was provided by Sanipur (Brescia, Italy) (Figure 1) and installed on the hot water system of this hospital. The system generated monochloramine by combining two reagents: 1) a stabilized chlorine precursor (Enoxin) and 2) a buffered ammonium salt solution (Zebion). These chemicals were injected into a pre-dilution loop that supplied monochloraminated water to the building circulating hot water system. Hot water Oxidation-Reduction Potential (ORP) and cold water flow feeding the hot water system were continuously monitored for control of monochloramine injection.

Samples from 27 distal outlets, the hot water return line, incoming cold water, and each of the two hot water tanks (before and after flushing) were cultured for *Legionella, Pseudomonas aeruginosa*, *Stenotrophomonas maltophilia*, *Acinetobacter* spp., nitrifying bacteria, *Mycobacterium* spp., and Heterotrophic Plate Count (HPC) bacteria once per month for the first six months of the study and every two months for the remainder of the study. For *Legionella*, *Acinetobacter*, Stenotrophomonas, and *Mycobacterium* water was plated directly and after 100mL was filtered and resuspended in 10 mL of sample. *Pseudomonas* and HPC were cultured according to Standard Methods[5].

Copper, silver, lead, monochloramine, total chlorine, free chlorine, nitrate, nitrite, total ammonia, pH, and hot water temperature were also measured throughout the study at least once per sampling month.

Results

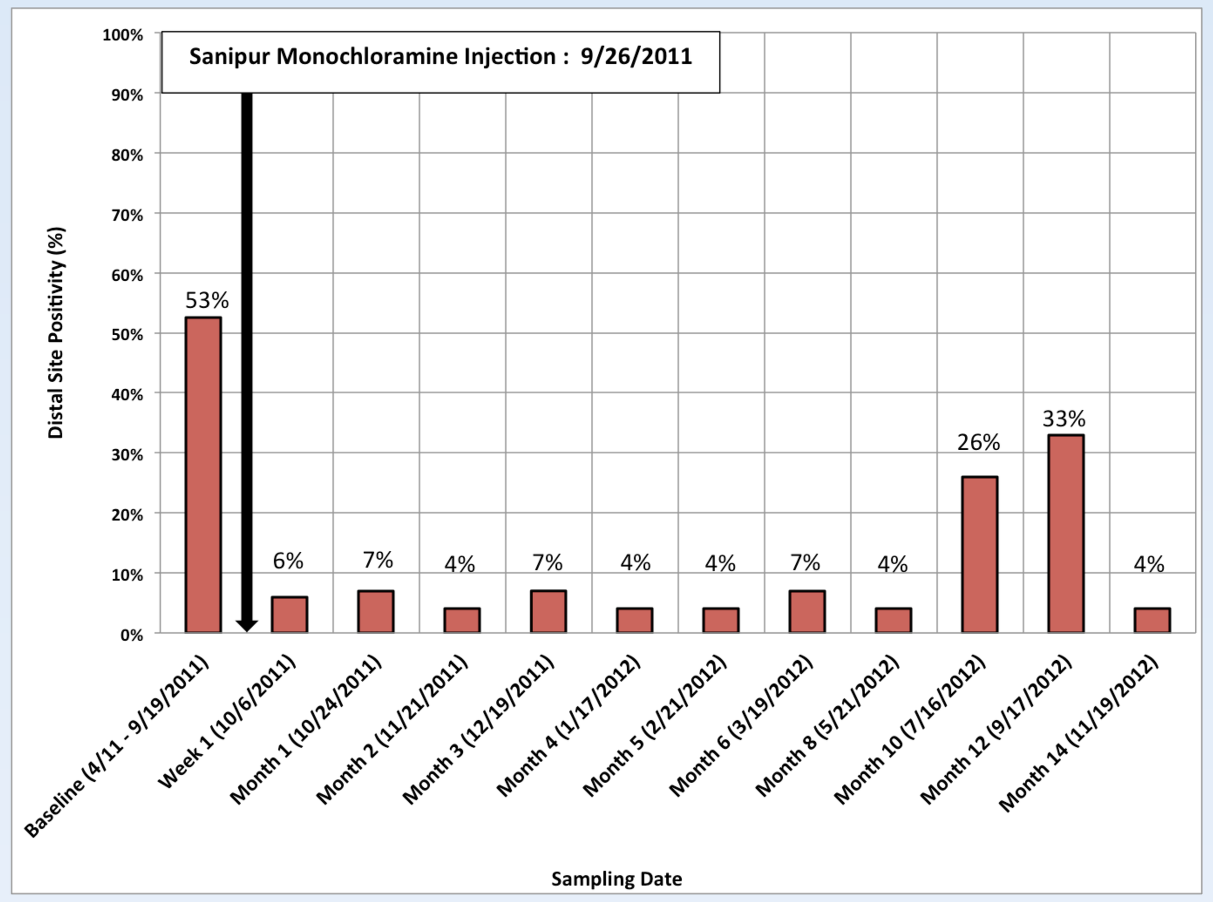

Figure 2. Decrease in *Legionella* percent positivity for 14 months following monochloramine injection

The percentage of positive distal sites decreased from an average baseline level of 53% to 6% after one week and an average of 10% during the 14 months of system operation (Figure 2).

Legionella positivity increased during months 10 and 12 to 26% and 33%, respectively (Figure 2). This was preceded by degradation of the stabilized chlorine solution which resulted in suboptimal monochloramine generation and increased ammonia in the hot water system. Once corrected positivity decreased to 4%.

Weekly monochloramine concentrations averaged between 1.56 and 3.03 mg/L as Cl_2 with an overall average of 2.22 mg/L as Cl_2.

HPC concentrations decreased significantly, by approximately 1 log CFU/mL ($p < 0.05$) (Table 1).

Table 1. Microbiological Results: No. Positive/No. Tested (Avg. CFU/mL).

	Distal Samples										
Microorganism	**Baseline**	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M8**	**M10**	**M12**	**M14**
Legionella* spp.	58/110 (1-10)	2/27 (1-10)	1/27 (10)	2/27 (1-10)	1/26 (10)	1/27 (1-10)	2/27 (1-10)	1/27 (1-10)	7/27 (1-10)	9/27 (1-10)	1/27 (1-10)
Pseudomonas aeruginosa**	2/110 (6)	0/27 (0)	0/27 (0)	0/27 (0)	0/26 (0)	0/27 (0)	0/27 (0)	0/27 (0)	0/27 (0)	2/27 (1)	0/27 (0)
Stenotrophomonas maltophilia	1/110 (1)	0/27 (0)	0/27 (0)	0/27 (0)	0/26 (0)	0/27 (0)	0/27 (0)	0/27 (0)	0/27 (0)	3/27 (201)	1/27 (109)
***Acinetobacter* spp.**	0/110 (0)	0/27 (0)	0/27 (0)	0/27 (0)	0/26 (0)	0/27 (0)	0/27 (0)	0/27 (0)	0/27 (0)	0/27 (0)	1/27 (546)
***Mycobacterium* spp.**	10/17 (64)	6/17 (52)	8/18 (10)	3/8 (14)	7/18 (23)	6/18 (20)	6/18 (34)	10/18 (63)	7/18 (50)	8/18 (27)	6/17 (23)
HPC	110/110 (14,000)	(23/27) 7,380	(25/27) 434	(23/27) 1,020	(23/27) 5,790	(26/27) 35	(24/27) 483	(23/27) 7,590	(24/27) 769	(25/27) 1,310	(25/27) 591

* *Legionella* detection limit = 1-10 CFU/mL

** Concentration units: CFU/100mL

The other microbes tested (*P. aeruginosa*, *S. maltophilia*, *Acinetobacter* spp., and *Mycobacterium* spp.) did not exhibit significant changes in percent positivity or average concentration following treatment with monochloramine.

Mean values for the other chemicals measured were as follows: copper (0.22 mg/L), silver (0.044 mg/L), lead (<0.0025 mg/L), total chlorine (2.17 mg/L), free chlorine (0.17 mg/L), nitrate (2.38 mg/L), nitrite (0.005 mg/L), total ammonia (0.62 mg/L), pH (8.26), and the average hot water temperature was 112.8 ^{o}F.

Conclusions

- Application of monochloramine to the hot water system of a hospital was shown to be effective in controlling *Legionella* colonization and prevented cases of hospital-acquired Legionnaires' disease. The study is ongoing.
- Regular monitoring of monochloramine, ammonia, and *Legionella* must be performed to ensure optimal operation and performance
- Unlike municipal application of monochloramine to cold water, we did not observe increases in other bacterial populations or nitrate/nitrite
- Monochloramine is a promising disinfection method for *Legionella* control in hospital water systems and should be evaluated in controlled studies in other healthcare institutions

References

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